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SUBJECT: AAP Docking Simulation - Case 620

DATE: December 11, 1969

FROM: R. J. Ravera

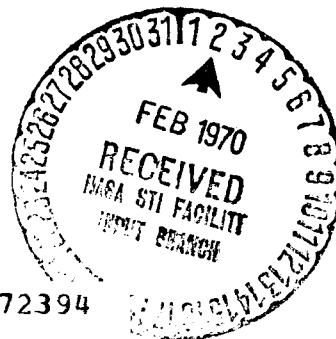
ABSTRACT

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The analytical docking simulation program, SDØCK, has been run with current AAP configuration mass data. In general, prospects for successful docking of the present AAP vehicles appear favorable. Reduced initial miss distance, offset angle, lateral velocity and angular rate of the chase vehicle (CSM) enhance the probability of success. Increased initial axial velocity (within specified range) of the chase vehicle is especially effective. Finally, axial thrusting of the chase vehicle virtually ensures capture.

(NASA-CR-107829) AAP DOCKING SIMULATION
(Bellcomm, Inc.) 8 p

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MEMORANDUM FOR FILEINTRODUCTION

The analytical docking simulation program, SDØCK,¹ has been run with current AAP mass properties data.² Some minor changes have been incorporated in the basic program. SDØCK now prints out relative translational velocities, angular velocity and offset angle of the target and chase vehicles just prior to a successful dock. This information can be employed to obtain the post-docking loads through the probe head-drogue interface. Since SDØCK already prints out pre-capture impact loads, a complete load history of the docking maneuver can be derived.

VEHICLE PROPERTIES

Mass properties used in the simulation were obtained from Reference 2 and are listed here for convenience.

CSM (Chase Vehicle) Mass - 860 slugs

SWS* (Target Vehicle) Mass - 4060 slugs

CSM Moment of Inertia - 50,000 slug-ft.²

SWS Moment of Inertia - 2,200,000 slug-ft.²

A mass center offset of 2.6 ft in the SWS was used, accounting for the deployed ATM. Finally, a reduced value for coefficient of restitution was used since previous results were felt to be overconservative** with respect to loads and performance.

INITIAL CONDITIONS

The five parameters required to set initial conditions are defined and illustrated in Figure 1. The array of cases covered in the runs is defined as follows:

*Saturn Workshop

**Based on conversations with J. Schliesing, MSC.

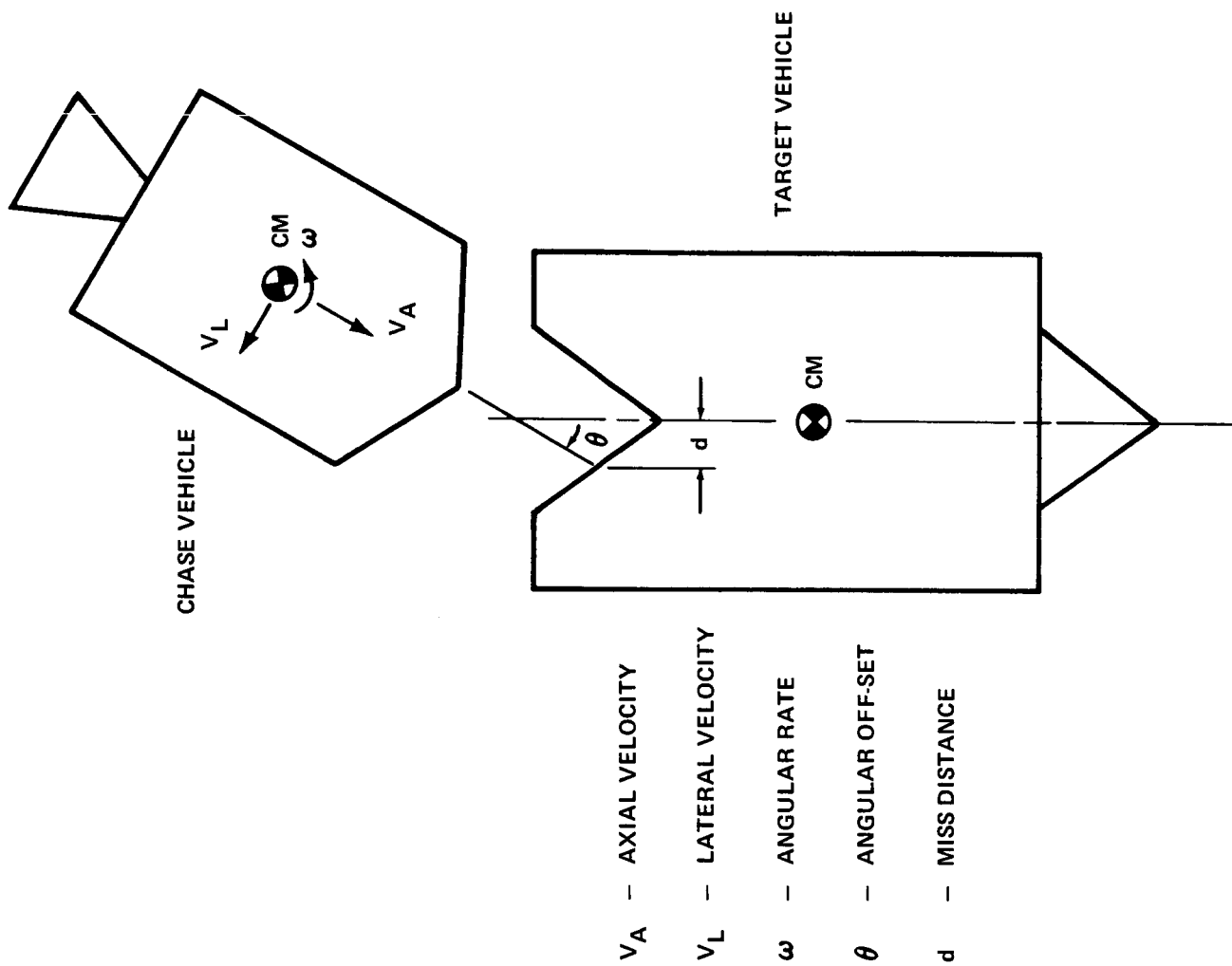


FIGURE 1 - INITIAL CONTACT PARAMETERS

$$V_A \text{ (ft/sec)} = 0.2, 0.4, 0.6, 0.8, 1.0;$$

$$V_L \text{ (ft/sec)} = 0.0, \pm 0.1, \pm 0.3;$$

$$\omega \text{ (deg/sec)} = 0.0, \pm 0.5;$$

$$\theta \text{ (deg)} = 0.0, \pm 5.0;$$

$$d \text{ (ft)} = 0.25, 0.50, 0.75$$

This represents a total of 675 sets of initial conditions. Additionally, each set of initial conditions was run in the following modes:

- 1) attitude control without CSM axial thrust
- 2) attitude control with CSM axial thrust

Therefore, a total of 1350 docking simulations were run. The number of ill-defined cases (negative closing rate) is 36. Some additional runs were made to assess the effects of (i) full CSM axial thrust without attitude control since command sharing of attitude control jets between axial thrusting and attitude control reduces total axial thrust available and, (ii) initial impact being towards or away from the offset SWS mass center.

RESULTS

Figures 2 and 3 are the capture boundaries derived from the runs. Regions on the hatched sides of the curves represent regions of no capture or, at best, low probability of capture. The most significant result is that general conclusions cannot be drawn from simulations made with specific vehicles. Vehicle configurations and mass properties can strongly influence capture boundaries as may be observed by comparing Figures 2 and 3 in this memorandum with Figures 4, 5, and 6 in Reference 1. With respect to the specific configuration under study, each parameter will be dealt with individually.

A. Miss Distance, d

Figure 2 indicates clearly that increasing miss distance decreases the probability of successful capture. Impacting within 0.25 ft of the drogue apex will almost ensure capture, regardless of other conditions. A miss distance of 0.75 ft seems to deny capture in 60% of the docking parameter envelope.

B. Angular Offset, θ

In this case, angular offset within $\pm 5.0^\circ$ did not seem to have any pronounced effect. It appears that the slight advantage is to the zero offset angle condition.

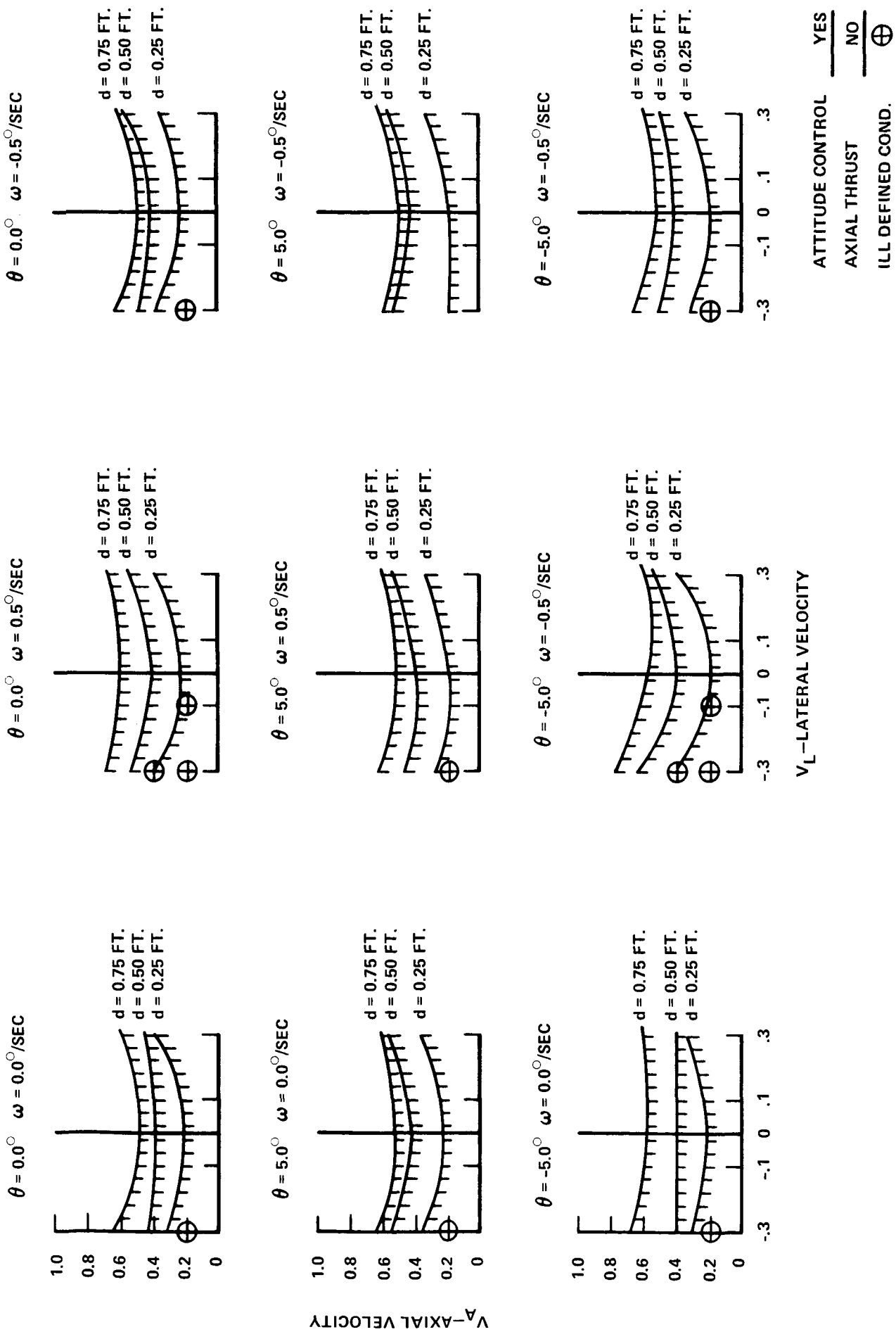


FIGURE 2 - AAP DOCKING BOUNDARIES

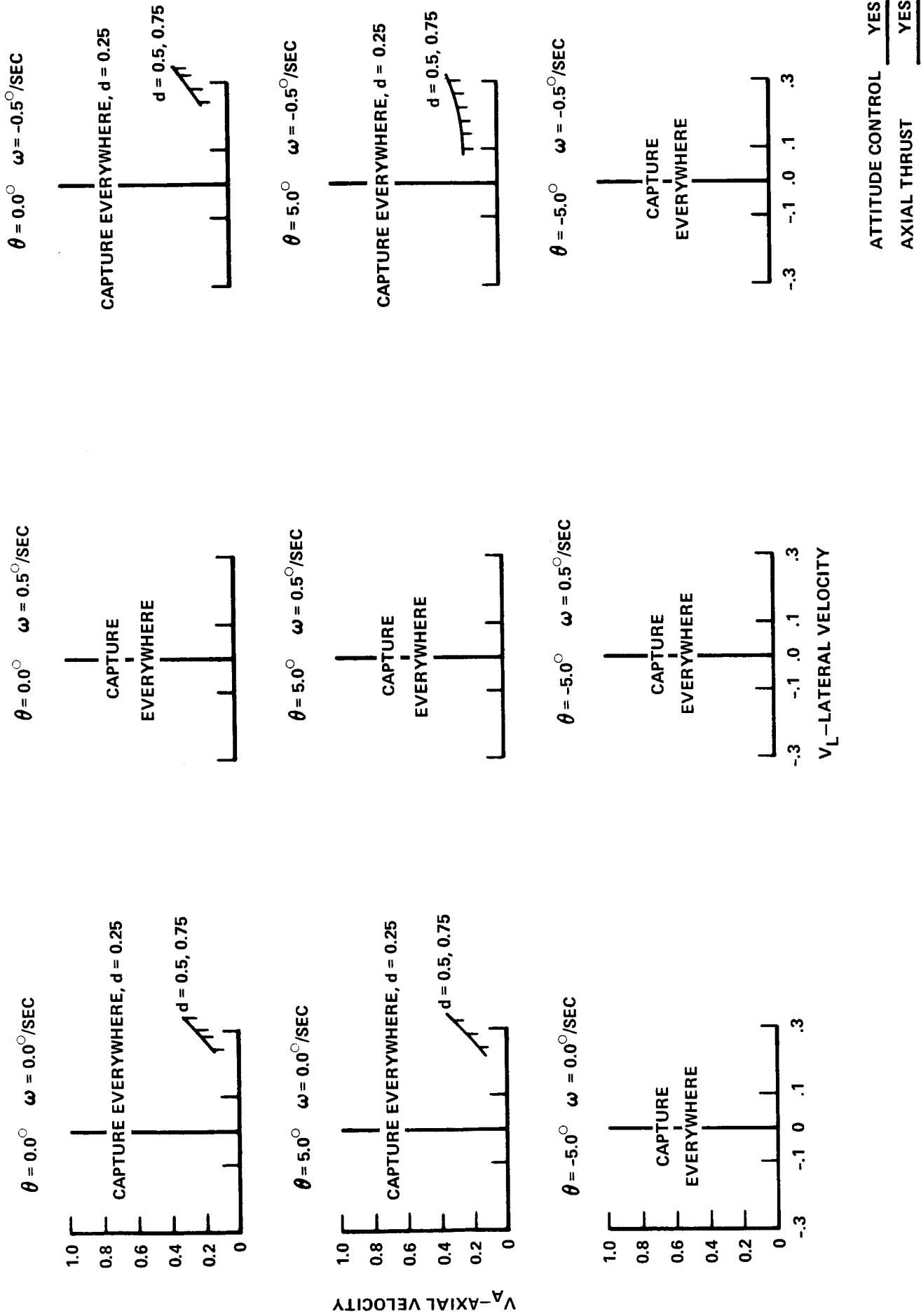


FIGURE 3 - AAP DOCKING BOUNDARIES

C. Angular Rate, ω

The same comments made in paragraph B apply here. For $-0.5 \text{ deg/sec} \leq \omega \leq 0.5 \text{ deg/sec}$ the slight advantage is with the zero angular rate condition.

D. Lateral Velocity, V_L

A zero lateral velocity is most favorable. The effect of lateral velocity decreases with increasing axial velocity.

E. Axial Velocity, V_A

Increasing axial velocity clearly increases the probability of capture. For the configuration under study, the condition $0.8 \text{ ft/sec} \leq V_A \leq 1.0 \text{ ft/sec}$ appears to ensure capture for the range of other parameters considered.

F. Axial Thrust

From Fig. 3, it is clear that for the range of parameters considered in this report, application of axial thrust (mode 2) virtually ensures capture.

Based on the results of Paragraph F, it seemed unnecessary to run the full set of initial conditions for a full axial thrust (no attitude control) mode. No substantial improvement in this mode over mode 2 was apparent in the few test runs made; indeed, there is not much room for improvement. Finally, the effect of the initial impact point relative to the mass center offset is negligible with respect to loads and performance. Impact loads for the case where initial contact and mass center are on the same side of the vehicle center line are within 2.5% of the loads for which initial contact and mass center offset are on opposite sides of the center line.

CONCLUSIONS

Prospects for successful docking of the present AAP vehicles appear favorable and if all parameters are within tolerance, capture can be virtually ensured by applying axial thrust.

Future work on docking dynamics includes development of complete docking load-time histories which can be applied to the flexible model of the SWS being developed by Bellcomm's Structural Dynamics Group.



R. J. Ravera

1

REFERENCES

1. "Docking Dynamics Simulation for AAP," R. J. Ravera,
Bellcomm TM-69-1022-6, July 24, 1969.
2. "AAP Cluster Mass Properties and CMG Control Capability,"
W. W. Hough, Bellcomm Memorandum for File, November 20, 1969.

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